

A 21st Century Approach to Reliability Program Overview

Mark Law, Toshi Nishida, Scott Thompson, Gijs Bosman

Department of Electrical and Computer Engineering

Steve Pearton, Cammy Abernathy, Brent Gila, Kevin Jones

Department of Materials Science and Engineering

Fan Ren

Department of Chemical Engineering



Agenda and Logistics

- | | | |
|-------------|---|---|
| • 0830-0840 | Kitt Reinhardt – Perspectives | Presentations at:
www.reliability.ece.ufl.edu |
| • 0840-0910 | MURI Overview (Mark Law) | |
| • 0910-0925 | Tester Capabilities (Dave Cheney) | |
| • 0925-1005 | Device Failure Measurement (Erica Douglas) | |
| • 1005-1030 | Break | |
| • 1030-1100 | Optical Pumping Experiments (David Cheney) | |
| • 1100-1130 | Material Characterization (Ryan Davies) | |
| • 1130-1200 | AFRL PACE Program (Don Dorsey) | |
| • 1200-1300 | Lunch | |
| • 1300-1350 | Effect of Mechanical Stress on GaN HEMT Channel Resistance and Gate Current (Nishida, Gupta, Koehler) | |
| • 1350-1420 | Noise Characterization of Stress Devices (Gijs Bosman) | |
| • 1420-1450 | Break | |
| • 1450-1510 | Inverse Piezoelectric Measurements (Mark Law) | |
| • 1510-1530 | Electro-Thermal Simulation (Michelle Griglione) | |
| • 1530-1600 | TEM and LEAP of Stressed Devices (Ray Holzworth) | |
| • 1600-1700 | Caucus and Feedback | |
| • 1700 | Adjourn | |

Outline

- Background
- Goals and Objectives
- Progress



Lifetime Prediction

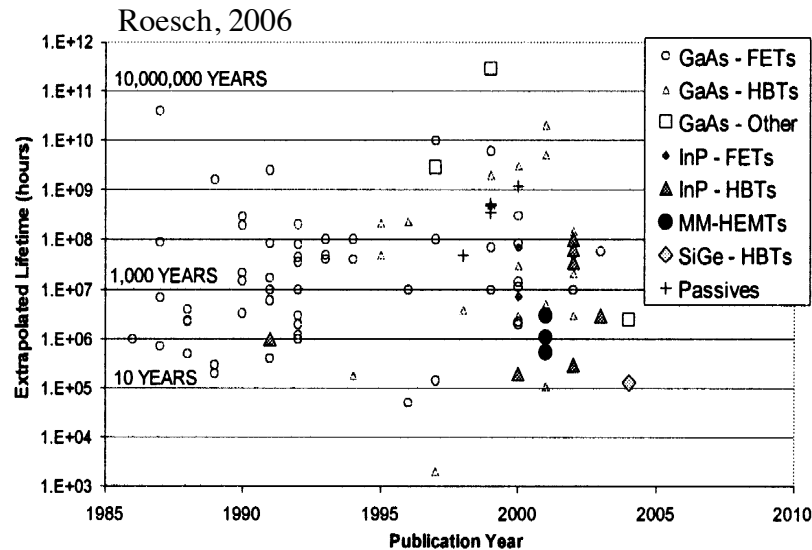
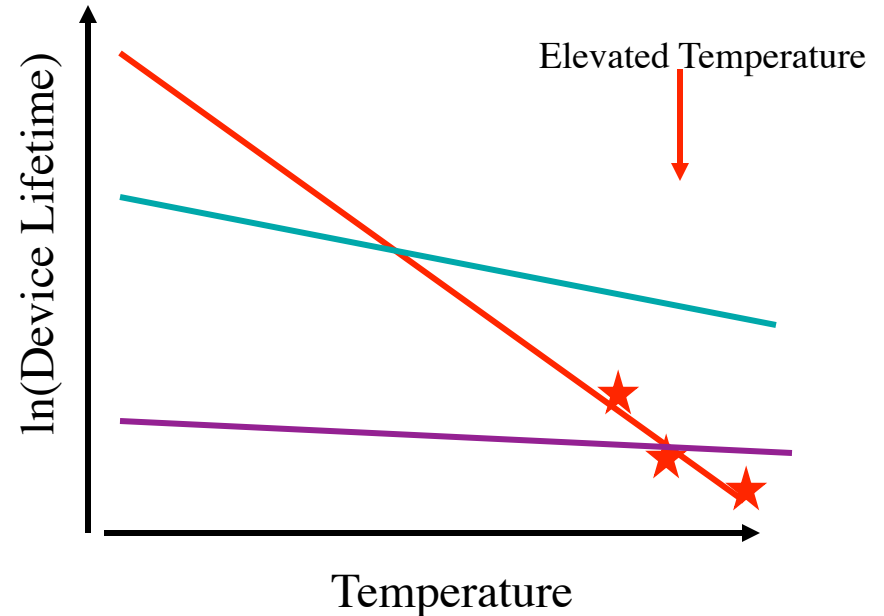


FIGURE 1. REPORTED OPERATING LIFETIMES FOR VARIOUS COMPOUND SEMICONDUCTORS OVER THE 19 YEAR HISTORY OF THE ROCS WORKSHOP^[1]



- Project Life Time
- Temperature Acceleration Approach
- Modeling is critical in extrapolation

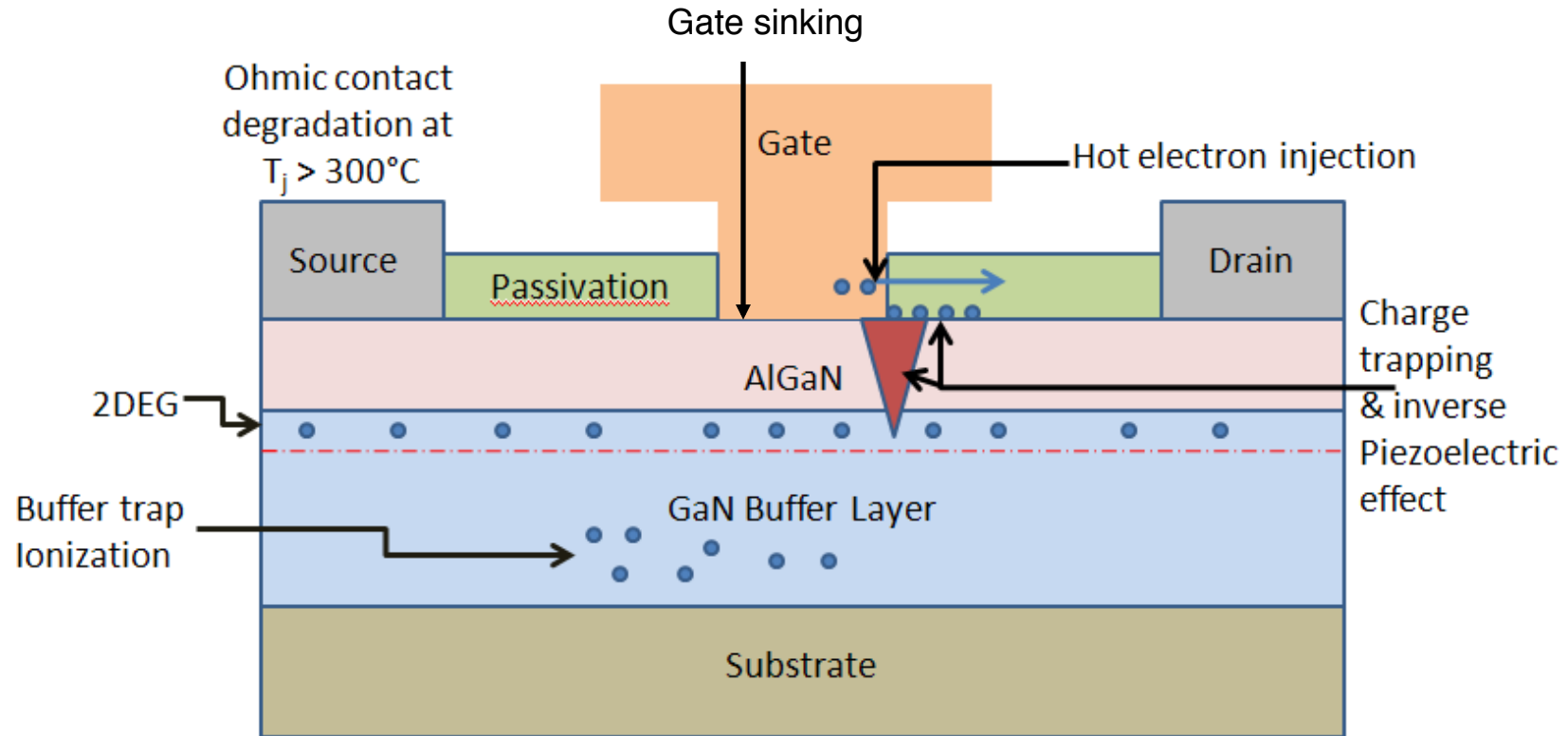
Precompetitive Engineering Scientific Research Focus

- Scientific Understanding of Materials Properties
- Understanding of Electrical Signatures
- Modeling / Simulation of Failure

- Black's Equation Empirically Captured Aluminum Electromigration in 1969
- Subsequent work on
 - Characterization of field, current density, temperature dependence
 - Characterization of mechanical stress
 - Characterization of grain size diffusion along grain boundaries
 - Characterization of etch effects related to grain size
 - Full 3-Dimensional Grain Models

Recent Papers in 2008 and 2009 - 40 years of science based pubs

Degradation of GaN HEMT's

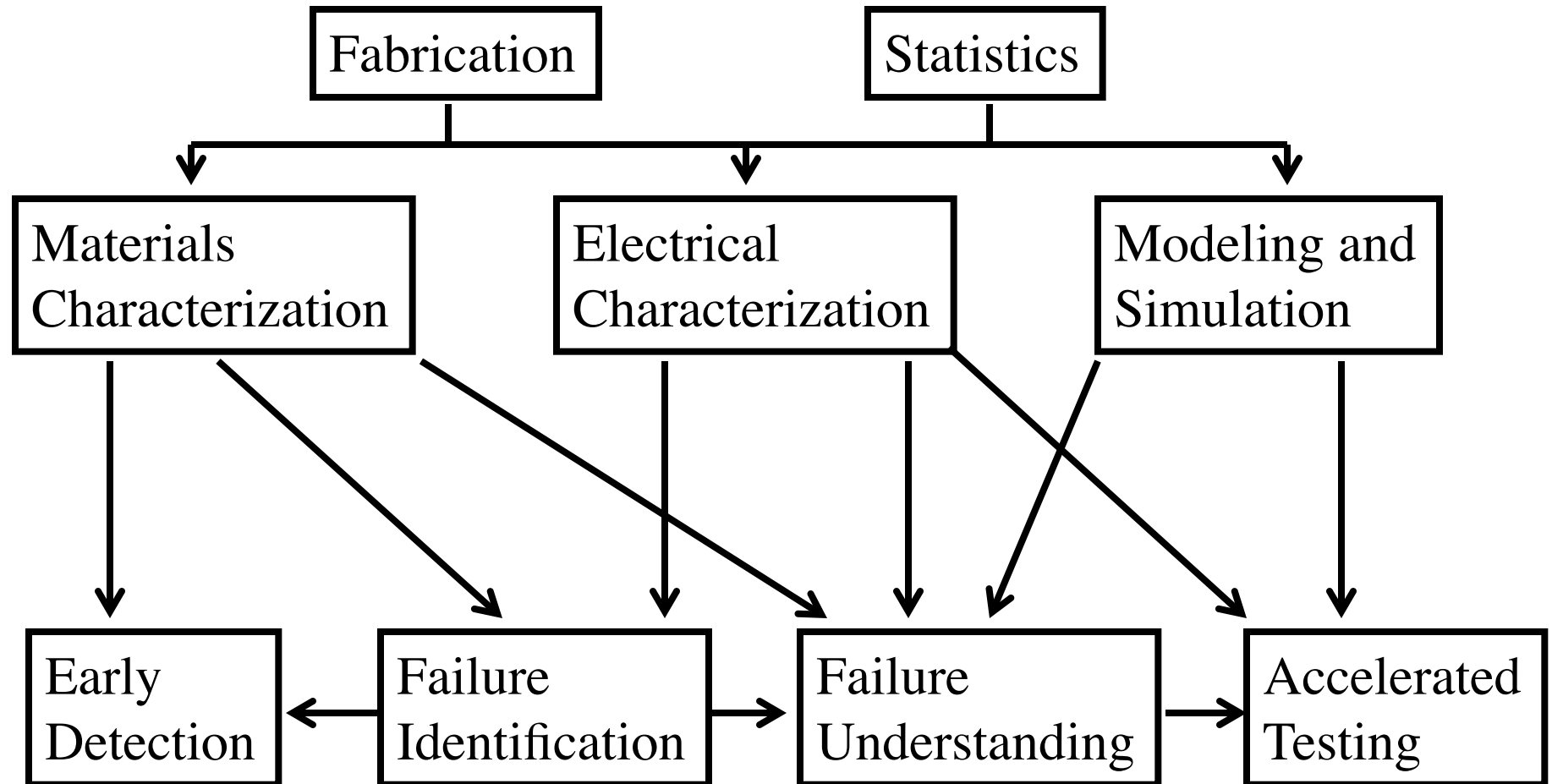


Objectives:

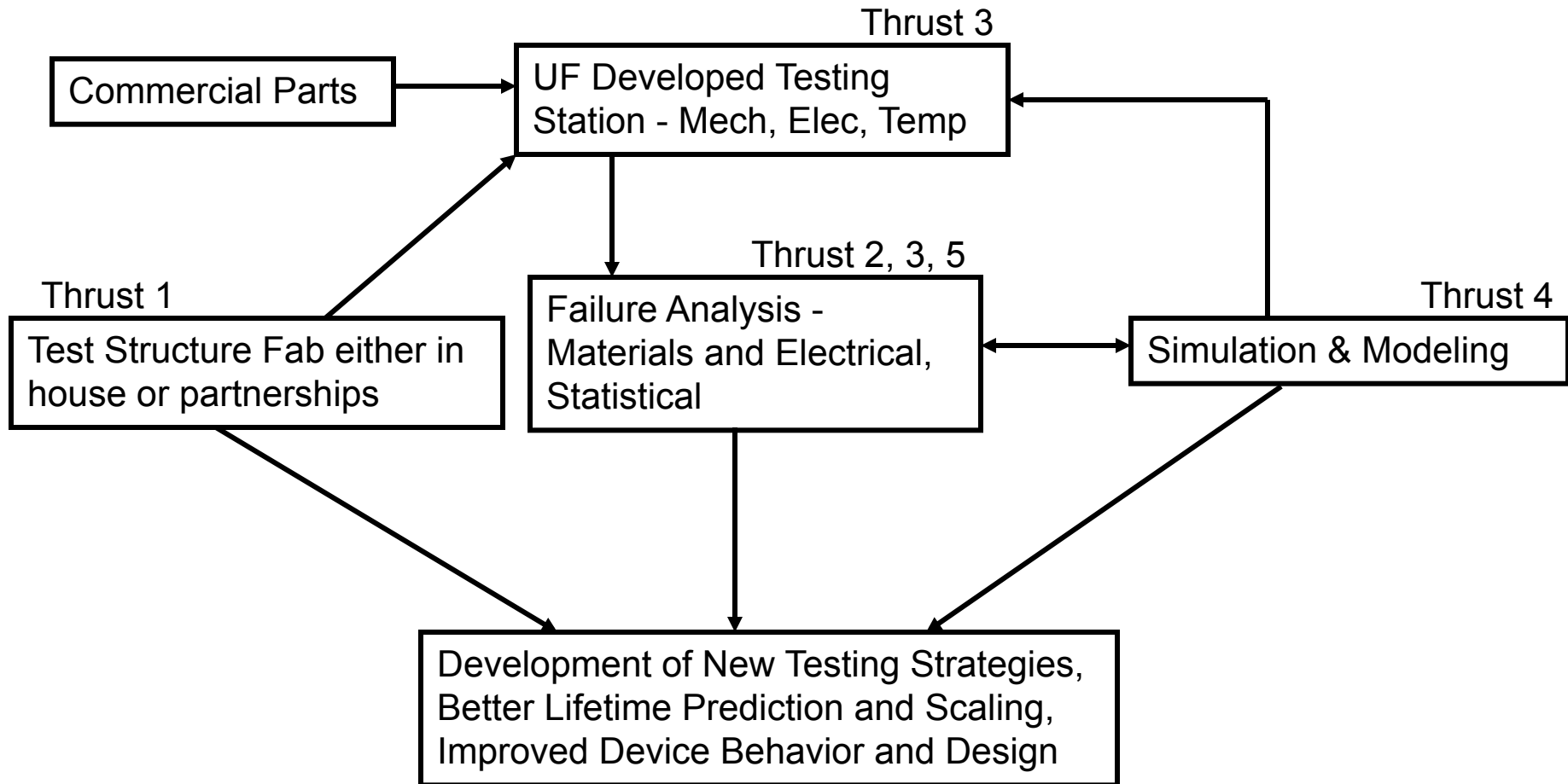
Develop a testing methodology for failure modes

Develop physical understanding of the failure modes


Thrust to Problem Relationships



Research Work Plan



Collaborations with Industry

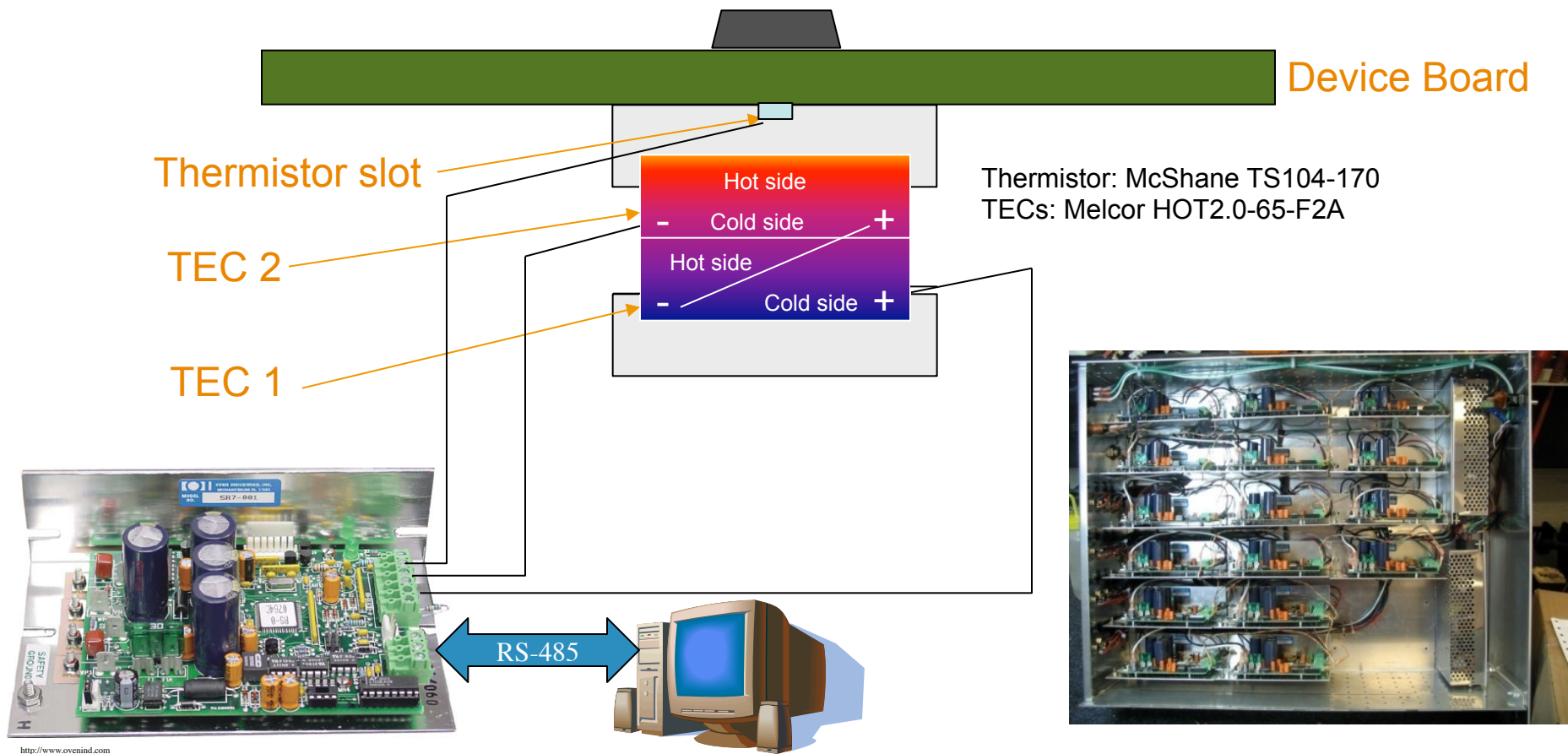
- RFMD 
- Nitronex 
- Win Semiconductor 
- Northrup Grumman 
- Air Force
 - MURI Funding / Input
 - PACE
 - Coordination w/ other Universities
 - Devices 
- ITAR / Export Control

ITAR / Export Control

- Controlled Room in NRF
- Devices kept in locked room and locked cabinet
- Sign in / sign out for experimentation
- ITAR Training Provided
- We can work with corporate devices
- Have controls in place



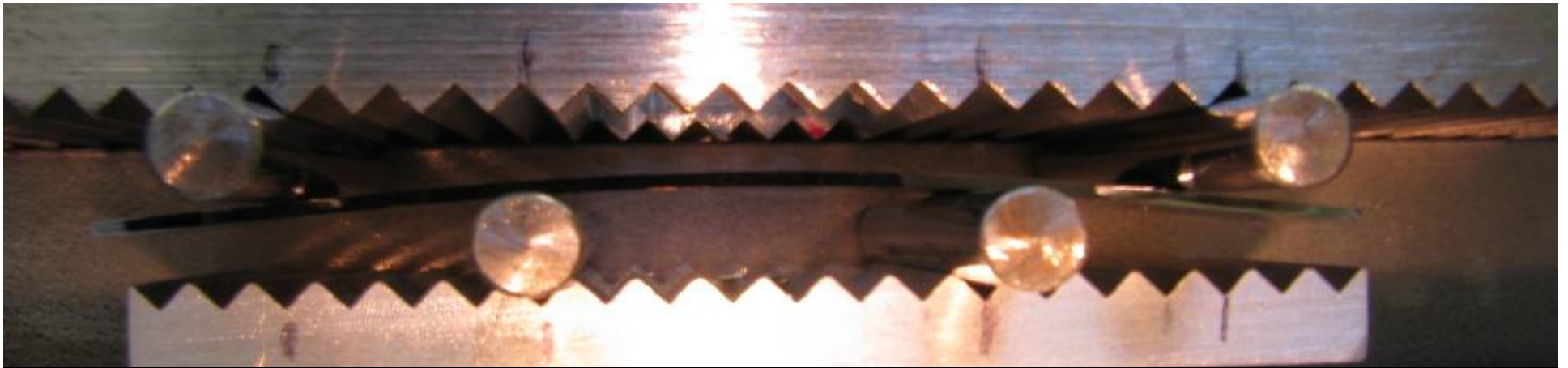
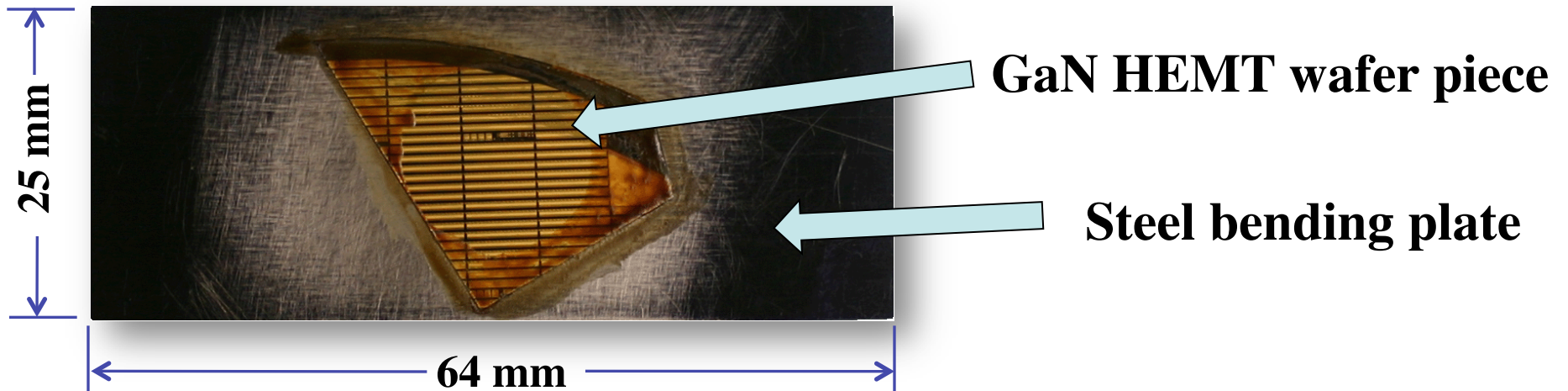
Device Burn-in and Fail



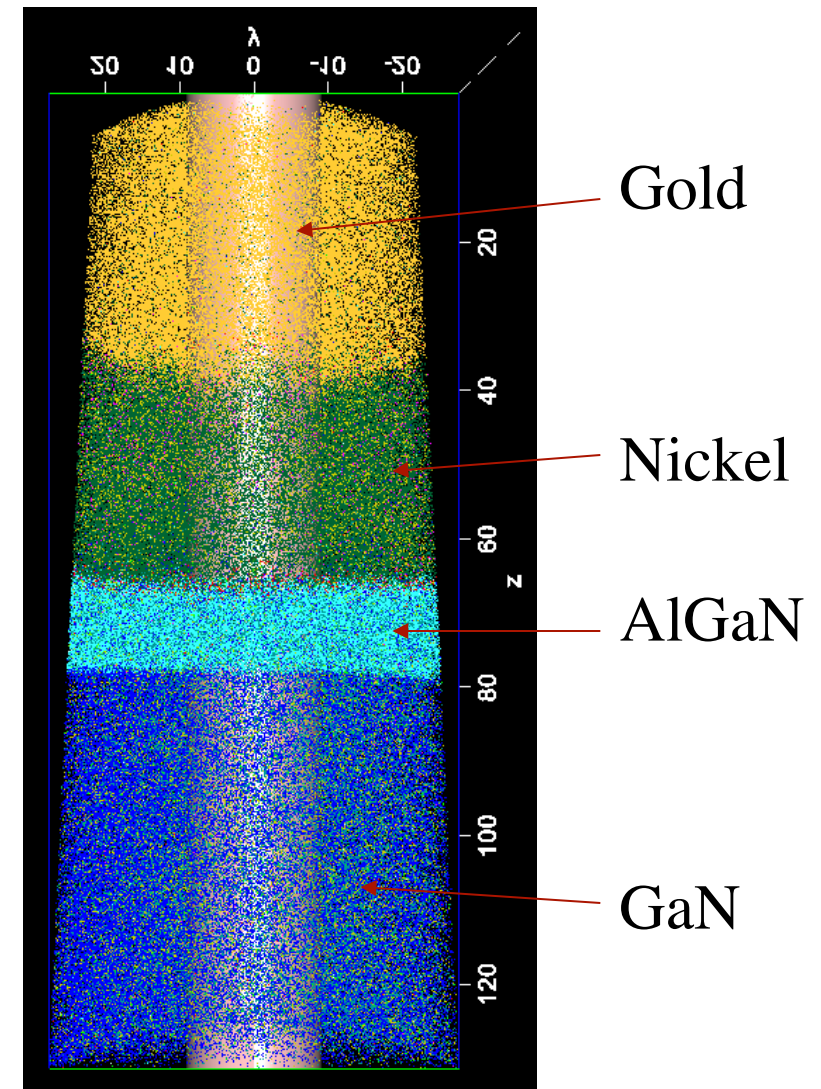
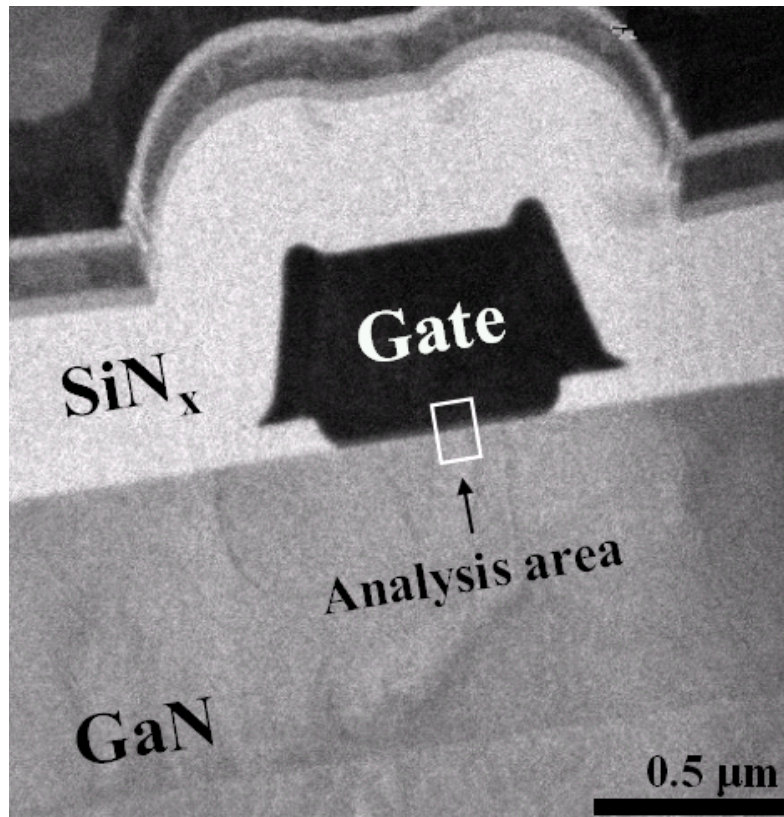
Temperature Measurement and Control

Fundamental Response Characterization

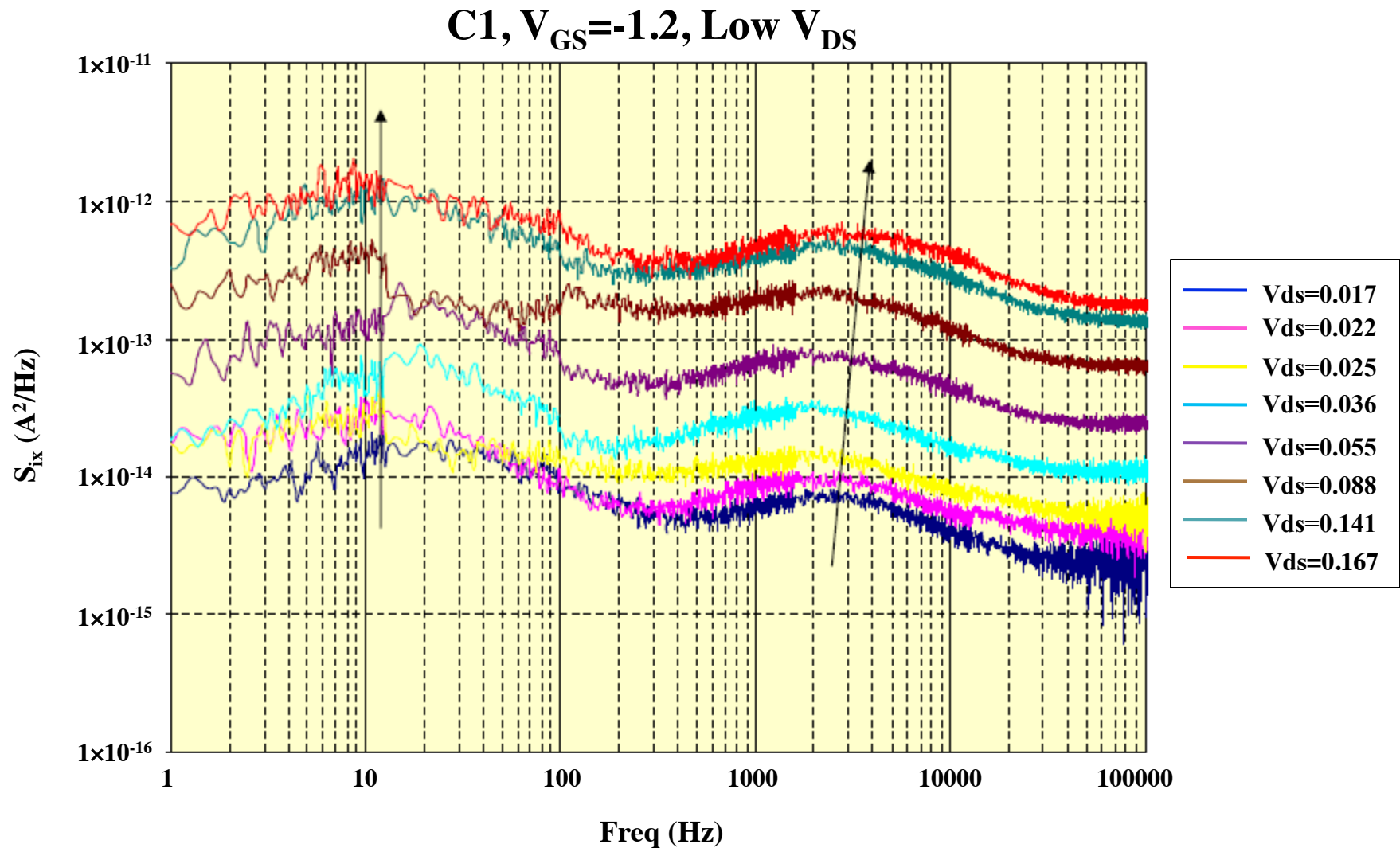
- GaN HEMT wafer samples too small to directly bend in 4-point bending setup
- Solution: (1) epoxy GaN HEMT wafer sample on high carbon stainless steel
(2) calibrate achieved strain by strain gauge measurements



Characterization – Fundamental and Failed Devices

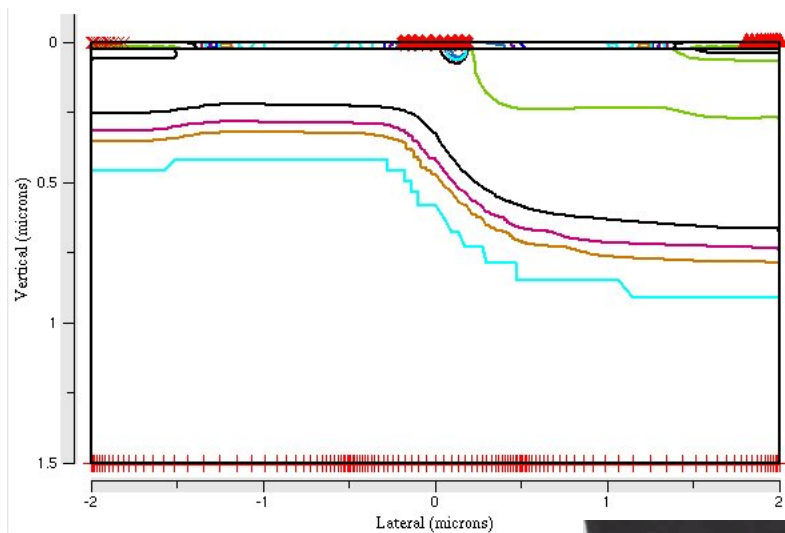


Characterization – Fundamental and Failed Devices

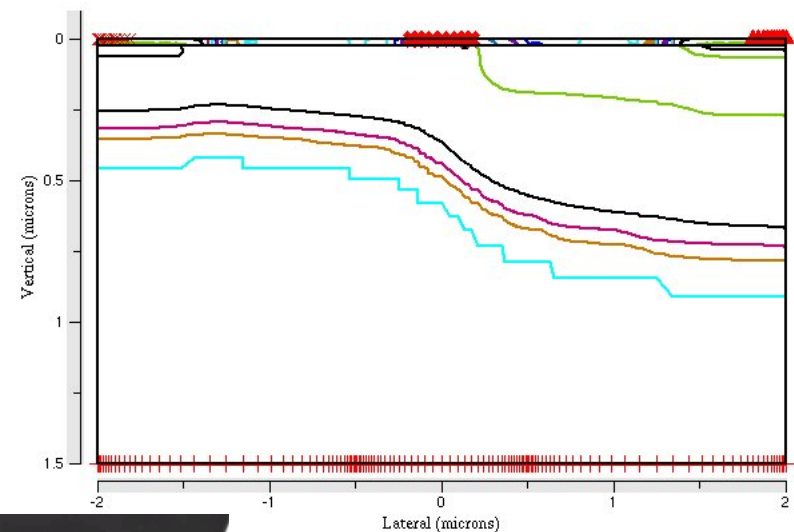


Inverse Piezoelectric Effect Calculation

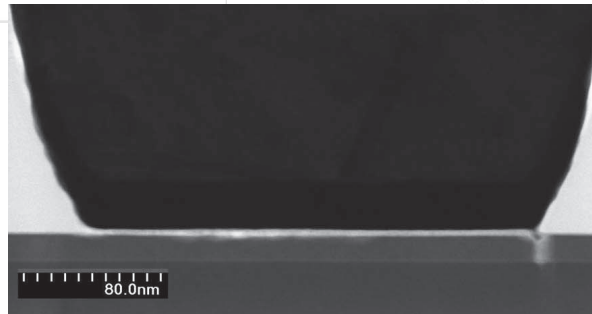
- Electro-Mechanical Simulation with InversePiezo
- 25V Drain - above the del Alamo threshold



Off State



On State



Conclusions

- Science Based Program
- Understanding Device Failure
- Characterization Techniques and Tools
- Full Coupled Reliability Simulation